# MASTER OF SCIENCE
# IN
# PHYSICS

**MEGAWATT CLASS FREE ELECTRON LASERS FOR NAVAL APPLICATION – SHORT RAYLEIGH LENGTH AND STABILITY ANALYSIS**

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A MW class free electron laser capable of delivering energy at the speed of light can improve ASCM defensive capability for Navy ships. Many design challenges must be overcome to make such a weapon possible. One such challenge is to maintain the power density on laser cavity mirrors at acceptable levels. The use of a short Rayleigh length to increase beam spot size at the mirror is studied as a possible solution to this problem. In this thesis, it is shown that by using a short Rayleigh length FEL, power densities at the mirrors are significantly reduced without causing a noticeable reduction in performance.

For a short Rayleigh length FEL, the resonator cavity is sensitive to misalignment and vibration. The effect of mirror tilt due to vibrations is explored and the results show that as mirror tilt increases, FEL efficiency does decrease. However, a mirror tilt several orders of magnitude greater than currently achievable active alignment tolerances is required before the FEL efficiency is noticeably affected. In this thesis, it is shown that mirror tilt within achievable tolerance limits will not adversely affect the performance of a FEL.

**KEYWORDS:** Free Electron Laser, Short Rayleigh Length, Directed Energy Weapon, Mirror Stability

**PASSIVE DETECTION OF GASES IN THE ATMOSPHERE CASE STUDY: REMOTE SENSING OF $SO_2$ IN THE UV USING LINUS**

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An imaging UV spectrometer was used to study sulfuric plumes at Lassen Volcanic National Park, in an effort to identify and quantify SO2 presence. The NPS instrument, LINUS (Lineate Imaging Near-Ultraviolet Spectrometer), was taken to Lassen on September 13 and 14, 2002. Data taken there are compared to laboratory measurements of SO2 subsequently run at NPS. These data, along with additional measurements of platinum discharges for wavelength calibration, allow for comparison with atmospheric modeling calculations. Observations were modeled with the standard MODTRAN code. Comparisons between simulated and measured data showed minor indications of SO2 in the Lassen data. The gas concentration was estimated to be less than 10ppmv.

**KEYWORDS:** Gas Detection, Sulfur Dioxide, Remote Sensing, Ultraviolet (UV), LINUS, Spectral Imager, MODTRAN

**MEGAWATT CLASS FREE ELECTRON LASERS FOR NAVAL APPLICATION– SHORT RAYLEIGH LENGTH AND STABILITY ANALYSIS**

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The free electron laser (FEL) is theoretically capable of scaling up to a MW class laser for naval point defense. At such high power levels, the FEL's optics could be damaged. An FEL operating with a short Rayleigh length reduces intensity at the mirrors; however, the performance of short Rayleigh length FELs is unknown. This thesis presents simulations of Thomas Jefferson Laboratories' proposed 100 kW FEL operating with a short Rayleigh length, and of a proposed 1 MW FEL undergoing shipboard induced mirror vibrations. In the 100 kW FEL, Rayleigh lengths of 0.1L to 0.5L (where L is the undulator length) were simulated. Weak field gain increases as Rayleigh length decreases, indicating that short Rayleigh length FELs will start from spontaneous emissions. Final FEL efficiency also increases as Rayleigh length decreases, with the exception of a spike at the typical Rayleigh length design value of 0.3L. For the 1 MW FEL system, the high operating current acts to stabilize the optical mode against vibrations that result in mirror tilts of 0 to 400 microradians, where final output power was reduced 80%. When used in conjunction with an active mirror alignment system, output power of the 1 MW FEL is unaffected.

**KEYWORDS:** Free Electron Laser, Short Rayleigh Length, Directed Energy Weapon, Mirror Stability